## Measurement of Liquid-to-Solid Nucleation Rates in Undercooled Metallic Melts

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The main objective of this work is to obtain quantitative experimental measurements of liquid-to-crystal *homogeneous* nucleation rates of undercooled metallic melts. Industrial melt and resolidification processes involve nucleation phenomena. Some of those processes rely heavily on a detailed understanding and control of either heterogeneous or homogeneous nucleation rates to produce a desired phase or microstructure. Avoiding or delaying nucleation enables the materials scientist to produce fine dispersions of second phase particles, to extend solubility limits, to refine the microstructure to the nanometer size range, and to synthesize novel crystalline and amorphous phases.

Experimental difficulties are encountered when working with molten metals. In particular, it has not been possible to either eliminate or fully characterize the foreign surfaces presented to the melt by particles, by container walls, or by suspending liquids. Attempts to remove these surfaces by processing metals containerlessly introduces problems in measuring temperature with sufficient accuracy. This study uses a novel experimental technique which allows a small metallic droplet to be formed, solidified, and remelted in high vacuum without physical contact. Temperature is measured by pyrometry. The same experimental apparatus also can be used to:

- expose droplets to controlled levels of gaseous reactants and/or particulate additives in order to make quantitative measurements of their influence on crystal nucleation;
- make quantitative measurements of critical cooling rates and time-temperaturetransformation diagrams for metallic glass-forming alloys; and,
- investigate whether there is a correlation between overheating and the undercooling limit.

This research will have several valuable outcomes. It will support the wide variety of solidification experiments of interest to microgravity investigators around the world. It can test theories for liquid-to-crystal nucleation in metallic melts. It can quantify the effect of some common trace impurities on crystal nucleation. In addition, this work, in conjunction with NASA's overall Microgravity Materials Science Program, will have a beneficial effect on countless industrial processes which involve the melting and resolidification of metals to produce a useful material.

In our experimental apparatus, droplet formation, positioning, and processing all occur in a ultra high vacuum stainless steel chamber sealed with copper gaskets. The droplets are fabricated under ultra high vacuum by electrohydrodynamic atomization. Molten droplets of various sizes in the micron range are ejected from the tip under the influence of the electric field, which is established between the end of the sample rod and a heating filament. Initially, the surface impurities (inevitably deposited during installation) are removed. Afterwards, clean droplets are produced. Note that the entire droplet fabrication procedure is accomplished in ultrahigh vacuum and *without* any physical contact.

Each droplet in the spray created in the atomizer moves downward, freezing at some point along its trajectory due to radiative cooling. Some of the frozen droplets move through a hole and into an

electrodynamic levitator (EDL). The EDL uses a vertical electric field to impart a counter-gravitational force on a charged particle. A simple feedback systems adjusts the top and bottom electrode potentials to keep the droplet vertically centered. An AC potential is placed on the center electrode to impart a centering force.

We have successfully electrosprayed 10 to 50 micron droplets of praseodymium, gold, and zirconium. We also have successfully levitated polystyrene beads and silver-coated hollow glass spheres in air. However, capturing electrosprayed metal droplets in the levitator has not yet been accomplished.